

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
18 September 2003 (18.09.2003)

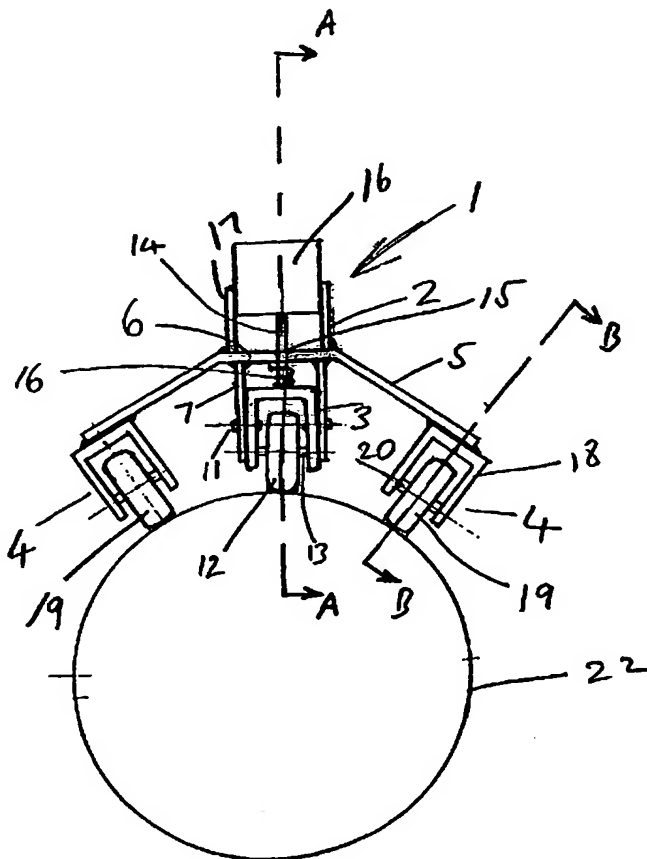
PCT

(10) International Publication Number
WO 03/076869 A1

- (51) International Patent Classification⁷: **G01B 5/08, 7/28**
- (21) International Application Number: **PCT/EP02/02788**
- (22) International Filing Date: **13 March 2002 (13.03.2002)**
- (25) Filing Language: **English**
- (26) Publication Language: **English**
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- (81) Designated States (national): AE, AG, AL, AM, AT (utility model), AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ (utility model), CZ, DE (utility model), DE, DK (utility model), DK, DM, DZ, EC, EE (utility model), EE, ES, FI (utility model), FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK (utility model), SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZM, ZW.
- (84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent

[Continued on next page]

(54) Title: APPARATUS FOR INSPECTING DEFORMATION OF PIPES



(57) Abstract: An apparatus (1) is provided for measuring deformation of a surface of a pipe (22). The apparatus has a central portion (2) to which a detector section (3) is mounted. At each side, guides (4) are connected to the housing via arms (5). The housing has a platform (6) below which an inverted U-shaped section (7) is provided, with the platform forming the base of the U. At the rear of this section a wheel is rotatably mounted on an axle. Forward of this, and also within the U-shaped section is mounted a further U-shaped section (10). This is pivotally mounted at its rear end by means of a pin such that its forward end is free to move vertically. The forward end has mounted within it a further wheel (12) on an axle (13). Projecting upwards from the second U-shaped section (10) is a rod (14) which passes through a hole (15) in platform (6). Around the lower portion of the rod is provided a spring (16) which biases the detector downwards and away from the platform. The rod moves vertically with the wheel (12) as it passes over bumps in the pipe. The rod is connected to a potentiometer which varies an output voltage. By correlating the variations in the output voltage with the distance moved by the detector, deformations in the pipe (22) may be mapped.

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(BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Published:

— *with international search report*

APPARATUS FOR INSPECTING DEFORMATION OF PIPES

5 The present invention provides an apparatus for
measuring deformation of pipes and tubes. The apparatus
is particularly useful in the field of chemical process
technology where deformation may be caused by uneven
heating of pipes and tubes. The invention also provides
10 a method of measuring deformation of pipes and tubes.

 In a thermal cracker unit where heat is used to
convert saturated hydrocarbons into unsaturated
hydrocarbons, the reaction mixture is generally passed
through a furnace in metallic reactor tubes. Cracker
15 units of this type are used in the process industry in
order to provide a feedstock of unsaturated hydrocarbon
for polymer production and other applications.

 In order to heat the hydrocarbon reaction mixture
in the reaction tubes of the cracker unit, a furnace is
20 generally provided in a chamber containing a large
number of cracker tubes which run parallel to one
another through the chamber e.g. the pipes may run
vertically from floor to ceiling of the chamber.
However, the positioning of the furnace burners relative
25 to the pipes has a tendency to cause hot spots in
various parts of the chamber, and as a result the pipes
are subject to temperature differentials. In
particular, one side of the pipe i.e. the side closest
to the heat source may be subject to higher temperatures
30 than the other side, and this leads to a problem with
circumferential creep i.e. deformation of the pipe
around its circumference.

 The working lifetime of the reaction tubes is
shortened by this phenomenon, and hence the tubes need
35 to be inspected regularly and replaced when they become
deformed. Indeed, if circumferential creep is not

detected in time and replacement tubes are inserted before the tubes fail, the cracker unit may have to be shut down immediately resulting in lost production time. At worst, this problem presents a serious safety risk.

5 Regular inspections of the cracker tubes are carried out when the cracker unit is shut down for routine maintenance and repair. However the existing methods of measuring the deformation of cracker tubes are time consuming and inefficient. Visual inspection
10 and manual measurement of pipe diameter/circumference is often inconvenient because the pipes are close to one another, impeding access to the pipes. Furthermore, scaffolding may be necessary in large chambers in order to reach the top part of the pipes.

15 Japanese Patent Application No. 08063873 of Japan Energy discloses an apparatus for inspecting pipelines by using a radiation source that is moved along the pipes to detect corrosion. This apparatus is however designed to detect corrosion in pipes, rather than
20 circumferential deformation. Furthermore, the method was developed to enable inspection of pipes without removing a heat insulation layer around the pipe. This renders the apparatus unnecessarily complex for use in cracker units in which the pipes are not insulated.

25 Japanese Patent Application No. 11-211700 discloses an apparatus that uses ultrasound to detect creep damage in pipes by determining the maximum roughness of the pipe. This it does by transmitting a sound wave into the pipe such that it passes through the pipe to a
30 circumferentially offset receiving probe. A further probe detects the echoes of reflected waves. However this apparatus is disadvantageous because as well as requiring a source of ultrasound and detector probes, comparatively complex calibration and analysis of the
35 output data is required.

It will therefore be seen that the prior art does not provide a cost-effective and efficient way to

measure deformation in pipes such as those found in petroleum crackers.

Viewed from one aspect, the invention provides an apparatus for measuring deformation of a surface of a pipe comprising a detector capable of directly detecting changes in the radius of a pipe and guide(s) for guiding the detector along the pipe in a direction parallel to the longitudinal axis of the pipe, whereby an output related to the deformation of the pipe surface is derived from the output of the detector.

Thus, the apparatus may be guided along a pipe which is being tested such that it directly measures changes in the radius of the pipe such as bulges caused by circumferential creep. The apparatus typically does this by the detector being arranged to measure the distance between a region of the pipe adjacent the detector and a part of the apparatus.

Although various sensing devices may be used, such as laser-based optical distance sensors, sonic sensors, etc., it is preferred that the detector is arranged to be placed in contact with the surface of the pipe and is moveable in the radial direction of the pipe. In this way, the deformation of the pipe surface may be determined from the displacement of the detector.

Such a measurement apparatus of the invention is ideally suited to measure the deformation of a pipe, especially cracker tubes, because it is mechanically simple and easy to operate. It is not expensive to manufacture and because of its simplicity it is easy to maintain.

Viewed from another aspect there is provided an apparatus for measuring deformation of a surface of a pipe comprising:

(i) detector means capable of detecting changes in the radius of a pipe when placed in contact with the surface of the pipe said detector means being moveable in the radial direction of the pipe at the point of

contact

(ii) a guide means capable of guiding the detector means along the surface of the pipe in a direction parallel with the longitudinal axis of the pipe, and

5 (iii) measurement means capable of measuring the radial displacement of the detector means whereby to produce an output related to the deformation of the pipe surface.

10 When the apparatus is in use, the moveable detector is contacted with the pipe and moved along its surface so that it moves over any bulges, bumps and recesses in the surface of the pipe. As the detector moves in the radial direction of the pipe, it remains in contact with the pipe surface as the pipe radius changes due to
15 deformation.

The displacement of the detector means is directly related to the radius of the pipe at the point of contact, and thus the output from the measurement means gives a qualitative, semi-quantitative or quantitative
20 indication of the circumferential deformation of the pipe at the point of contact.

The part of the detector that contacts the pipe may take any suitable form that allows it to maintain contact with the pipe surface whilst it moves over the
25 surface along the pipe. Thus, it may be a smooth surface, possibly provided with a bearing surface of, for example, nylon or a lubricated contact surface. However, the detector is preferably in the form of a rotatable member such as a wheel or roller which is able
30 to rotate freely so that it rolls smoothly over the surface of the pipe. This reduces noise and cuts down on wear to the device and the pipe.

A further advantage of using a rotatable member is that it may be used to determine the total distance
35 travelled by the detector in order to correlate output, concerning the pipe's condition with position. Thus, the number of rotations of the member may be counted. Other

rotatable members provided on the device may additionally or alternatively be used for this purpose.

As well as guiding the detector along the pipe, the guide(s) may assist in securing the apparatus firmly in position against the pipe. This is preferably achieved by providing the guide(s) with magnet(s) arranged to hold the apparatus in position against a steel pipe.

In order for the detector to be moveable in the radial direction of the pipe, the detector may conveniently be connected to the guide(s) in such a way that the detector is able to move in the radial direction of the pipe relative to the guide(s), whereas the guide(s) do not move in the radial direction of the pipe. For example, the detector may be attached to the apparatus by means of a pivoted arm, spring or other device which allows it to move in the direction required, i.e. radially from the centre of the pipe, when in use.

The guide(s) are provided in order to guide the detector longitudinally along the pipe. Thus, they maintain the course of the detector along its path, over the surface of the pipe without deviating laterally across the surface of the pipe, i.e. to keep the detector travelling parallel to the longitudinal axis of the pipe. In a preferred embodiment the guide(s) comprise two or more rotatable members such as wheels or rollers that are capable of maintaining contact with the surface of the pipe as the measurement apparatus is moved along the pipe. These members may be similar to the rotatable member discussed above that may be used in the detector.

Preferably, the rotatable members of the guides are connected to the detector means such that they are positioned either side of the detector and along an imaginary arc having approximately the same radius as the pipe under test. In this way, when the apparatus is in use, the detector and the guides are both in contact

with the surface of the pipe at different points around its circumference. It is particularly preferred that at least two of the rotatable members in the guide means are spaced apart from one another and from the detector
5 such that the distance between the detector and each said rotatable members is smaller than the radius of the arc (and hence smaller than the radius of the pipe under test).

Where the guide means comprises two or more
10 rotatable members as described above, the rotatable member of the detector may be movably mounted on a housing or platform with each guide member mounted on an arm extending laterally therefrom.

As explained above, the guide means is primarily
15 required in order to guide the detector means along the desired path on the pipe. However, the guide means may also provide other useful functions. Thus in a preferred embodiment, the distance travelled by the guide may be measured, for example by counting the revolutions of a
20 rotatable member, so that the position of the detector means may be found.

In addition, the guides provide a useful location
in which to mount other types of sensing apparatus such that more than one kind of measurement may be made at
25 the same time.

Of course if the position of the detector means is known at any given point along the pipe, the nature of the deformation of the pipe at each point on the pipe can be easily monitored. The shape and size of bulges,
30 bumps and recesses in the pipe at any given point can be mapped in this way. As well as providing direct information about the condition of the pipe under test, such information is extremely useful in building up a picture of the heat distribution inside a furnace when
35 it is in operation. This information is particularly useful to identify hot spots within the furnace chamber and it may be possible to make changes to the chamber

design to prevent the problem from reoccurring.

There are a number of ways in which to measure the displacement of the detector means relative to the centre of the pipe under test. A simple and effective
5 way is to use a linear potentiometer arranged to provide a varying output voltage in proportion to the displacement. This may be plotted against linear distance travelled along the pipe.

Although the apparatus of the invention can be
10 moved manually along the pipe it is preferred that the apparatus further comprises transporting means to transport the detector means along the pipe. Such means could take any suitable form such as a device which can be positioned at one end of the pipe with an extending
15 arm which moves the measurement apparatus in a straight path along the pipe. Many suitable mechanisms are known in the art that can achieve this.

It will be appreciated that the invention extends to a corresponding method of measuring deformation of a
20 pipe. Thus, viewed from another aspect, the invention provides a method of measuring the deformation of surface of a pipe using the apparatus of the invention.

Certain embodiments of the invention will now be described, by way of example only, with reference to the
25 accompanying drawings:

Figure 1 is an end view of a measurement apparatus in accordance with a preferred embodiment of the invention in use on a section of pipe;

Figure 2 is a sectional view along the line A-A of
30 the measurement apparatus of Figure 1;

Figure 3 is a sectional view along the line B-B of the measurement apparatus of Figure 1; and

Figures 4 and 5 are schematic views of the measurement apparatus of Figure 1 in use on normal and
35 deformed sections of pipe.

With reference first to figure 1, the apparatus 1 is formed with a central portion 2 to which the detector

section 3 is mounted. At each side, guides 4 are connected to the housing via arms 5.

As may also be seen from figure 2, the housing has a platform 6 below which an inverted U-shaped section 7 is provided, with the platform forming the base of the U. At the rear of this section a wheel is rotatably mounted on an axle 9.

Forward of this, and also within the U-shaped section is mounted a further U-shaped section 10. This is pivotally mounted at its rear end by means of a pin 11 such that its forward end is free to move vertically (in the sense of the figures). That forward end has mounted within it a further wheel 12 on an axle 13. These components together form a detector as will be discussed below.

Projecting upwards from second U-shaped section 10 is a rod 14 which passes through a hole 15 in platform 16. Around the lower portion of the rod is provided a spring 16 which biases the detector downwards and away from the platform.

The upper end of the rod 14 extends into an enclosure which is supported above the platform by supports 17. Within the enclosure is provided a linear potentiometer and associated components. Vertical movement of the rod 14 causes the potentiometer to change its resistance such that, when an external voltage is applied, an output voltage is provided in proportion to the movement of the rod. (The electrical components are not shown for reasons of clarity.)

As may be seen from figure 3, the guides 4 (which are similar to each other) comprise inverted U-shaped sections 18 mounted on the distal ends of arms 5. At the forward end of each is mounted a wheel 19 on an axle 20. In addition, behind each wheel is located a permanent magnet 21 (these are omitted from figure 1 for clarity).

In operation the apparatus is located on the outside of the pipe under test 22, as shown in figures 1

and 2, such that all four wheels make contact with the surface of the pipe. Wheels 8 and 19 together form a tripod arrangement and wheel 12 moves upwards against the bias force of the spring 16. The attractive force of the magnets 21 serve to hold the apparatus firmly in place against the pipe 22, despite the force of spring 16.

The guide wheels 19 and wheel 8 have parallel axes so they constrain the apparatus to move in a straight line along the pipe and parallel to its axis. It may be moved manually, or by means of an external driver on which it is mounted (not shown). As the apparatus moves, wheel 12 of the detector will move to follow the contours of the pipe - upwards for a bulge, downwards for a recess. As it moves, it causes a corresponding movement of rod 14 which in turn varies the resistance of the potentiometer, as discussed above. This in turn provides a variable output voltage representative of the contours of the pipe.

Figures 4 and 5 illustrate schematically the effect of a bulge in a pipe on the detector wheel 12. In figure 4 the pipe is level so wheel 12, mounted on section 3 is in a low position. In Figure 5 a bump is encountered which causes wheel 12 to be pushed up, causing section 3 to pivot against spring 12.

By comparing the output voltage with the corresponding position of the apparatus, the pipe may be mapped. This may be automated if, as in a modified embodiment (not illustrated), a device is provided to count the revolutions of wheel 8. This device takes the form of a reed switch that may be closed by a small magnet on wheel 8 as the wheel reaches its uppermost position. By using the reed switch to interrupt a circuit, a pulse is provided for every rotation of wheel 18. A pulse counter then provides a measure of the distance travelled. The output from the potentiometer and from the counter is then fed to a computer where a

plot of voltage (i.e. profile) versus pulses (i.e. distance along pipe) may be produced. This may, of course be calibrated to give readings in millimetres and metres respectively.

Claims

1. An apparatus for measuring deformation of a surface of a pipe comprising a detector capable of directly
5 detecting changes in the radius of a pipe and guide(s) for guiding the detector along the pipe in a direction parallel to the longitudinal axis of the pipe, whereby an output related to the deformation of the pipe surface is derived from the output of the detector.
- 10 2. An apparatus as claimed in claim 1, wherein the detector is arranged to measure the distance between a region of the pipe adjacent the detector and a part of the apparatus.
- 15 3. An apparatus as claimed in claim 2, wherein the detector is arranged to be placed in contact with the surface of the pipe and is moveable in the radial direction of the pipe such that the deformation of the
20 pipe surface may be determined from the displacement of the detector.
4. An apparatus as claimed in claim 1, 2 or 3, wherein the detector comprises a rotatable member that is
25 arranged to roll over the surface of the pipe.
5. An apparatus as claimed in any preceding claim, wherein the guide(s) comprise magnet(s) arranged to hold the apparatus in position against a steel pipe.
- 30 6. An apparatus as claimed in any preceding claim, having a plurality of guides, the guides comprising rotatable members spaced apart from the detector and arranged to contact a surface of the pipe when the
35 detector is in contact with the pipe.

7. An apparatus as claimed claim 6, wherein a said guide is provided on each side of the detector, the rotatable members of the guides and the detector being positioned substantially along an arc, and the distance
5 between each said rotatable member of the guide and the detector being smaller than the radius of the arc.

8. An apparatus as claimed in claim 7, wherein the rotatable member of the detector is movably mounted on a
10 housing and each guide member is mounted on an arm extending laterally from the housing.

9. An apparatus as claimed in any preceding claim comprising measurement means for measuring the
15 displacement of the rotatable member of the detector in relation to the housing.

10. An apparatus as claimed in any preceding claim wherein said apparatus further comprises transporting
20 means to transport the detector means along the pipe.

11. An apparatus as claimed in any preceding claim, arranged to measure the distance traveled by the apparatus along the pipe.
25

12. An apparatus as claimed in claim 11, wherein the distance traveled is determined by measuring the number of rotations of a rotatable member engaged with the pipe.
30

13. An apparatus for detecting deformation of a surface of a pipe comprising:

(i) a detector capable of detecting changes in the radius of a pipe when placed in contact with the surface
35 of the pipe, said detector means being moveable in the radial direction of the pipe at the point of contact;

(ii) a guide assembly capable of guiding the

detector along the surface of the pipe in a direction parallel with the longitudinal axis of the pipe; and

(iii) measurement means capable of measuring the radial displacement of the detector, whereby to produce
5 an output related to the deformation of the pipe surface.

14. A method of measuring the deformation of surface of a pipe using the apparatus as claimed in any preceding
10 claim.

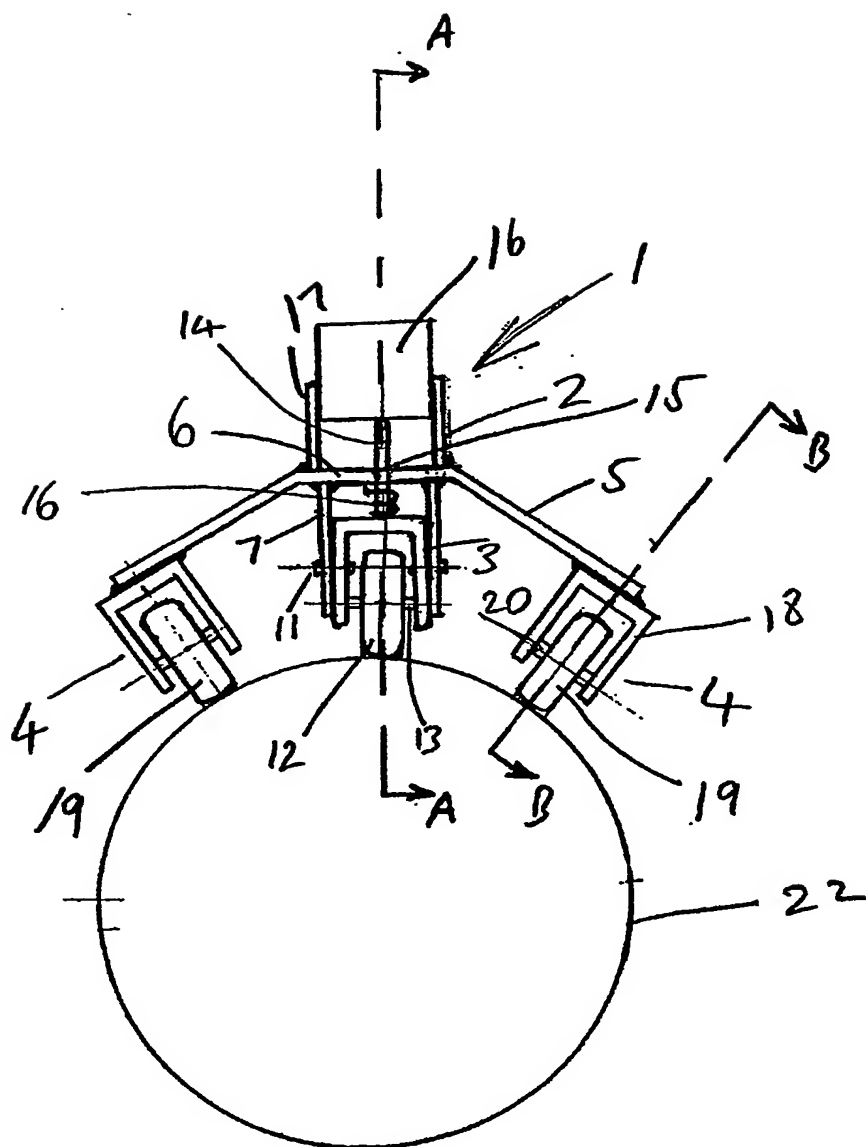


Fig 1

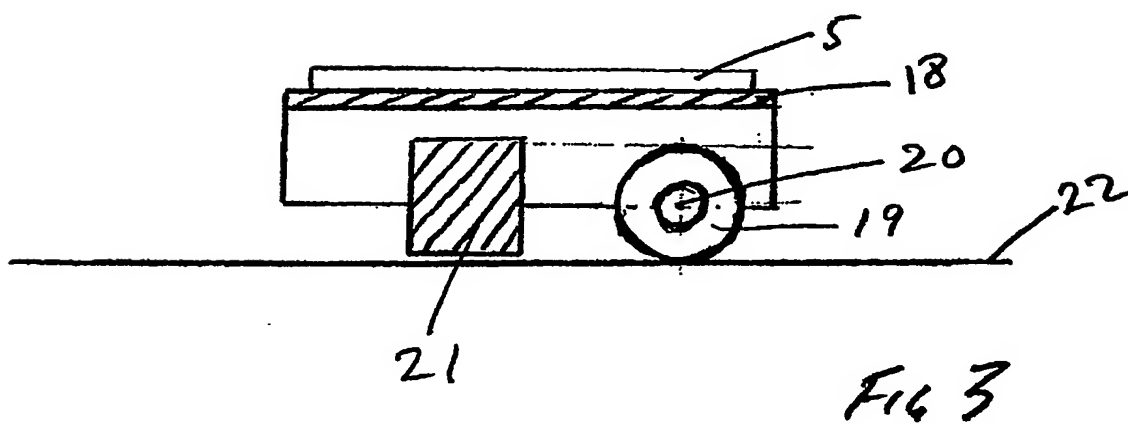
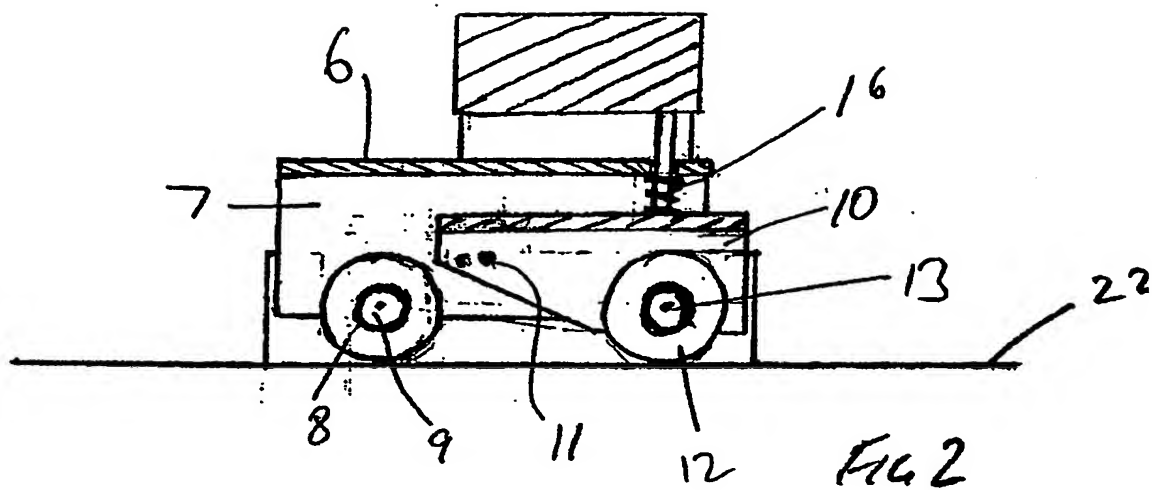


Fig 5

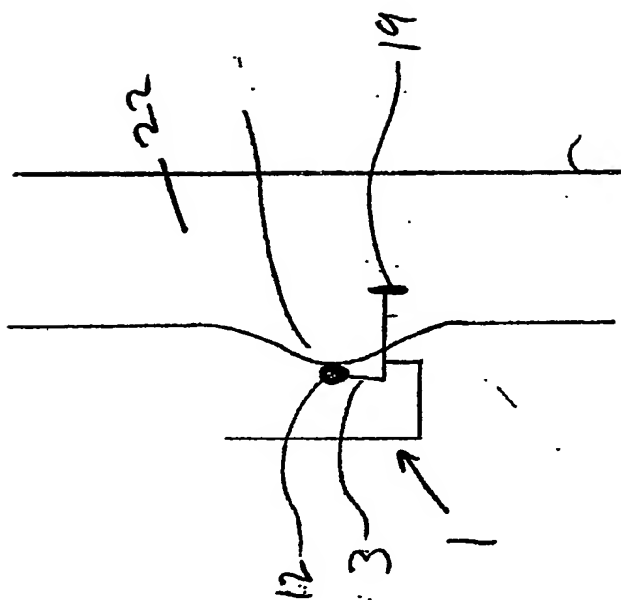
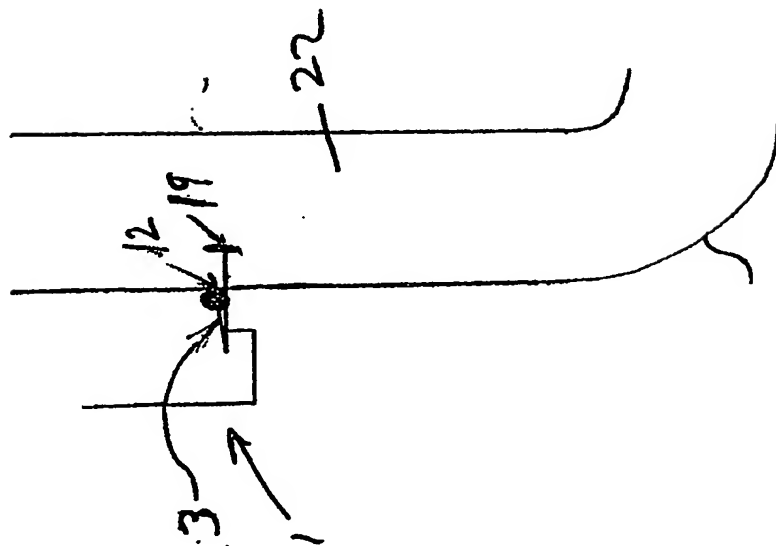


Fig 4



INTERNATIONAL SEARCH REPORT

National Application No

PCT/EP 02/02788

A. CLASSIFICATION OF SUBJECT MATTER
 IPC 7 G01B5/08 G01B7/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 011, no. 049 (P-547), 14 February 1987 (1987-02-14) & JP 61 215901 A (KAWASAKI STEEL CORP; OTHERS: 01), 25 September 1986 (1986-09-25) abstract	1-3, 13, 14
X	US 4 240 206 A (BARESH JOSEPH M ET AL) 23 December 1980 (1980-12-23) the whole document	1-4, 6-8, 13, 14
X	US 5 335 422 A (FERGUSON CLAYTON L) 9 August 1994 (1994-08-09) the whole document	1, 2, 4, 6-14
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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

13 November 2002

Date of mailing of the international search report

21/11/2002

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INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/02788

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 389 788 A (BALOGH LOUIS J ET AL) 28 June 1983 (1983-06-28) the whole document -----	1-3, 13, 14

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 02/02788

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
JP 61215901	A	25-09-1986	NONE	
US 4240206	A	23-12-1980	NONE	
US 5335422	A	09-08-1994	NONE	
US 4389788	A	28-06-1983	CA 1188092 A1	04-06-1985